VARIATION OF FIELD-STRENGTH IN THE VICINITY OF AN ULTRA-SHORT-WAVE HORIZONTAL TRANSMITTING AERIAL *

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ABSTRACT. The intensity of radiated field-strengths in the neighbourhood of an ultra-short-wave horizontal transmitting aerial has been determined and its variation with different angular directions with respect to the aerial has been studied. For the purpose of radiation a modulated valve oscillator generating waves of 6.1 metres in length was employed along with a half-wave horizontal aerial. A calibrated ultra-short wave receiver was used for the determination of field-strengths. The observed values of field-strengths were compared with those calculated mathematically. In order to study the directional quality of such an aerial the angular tracks of maximum and minimum amount of energy-flow have been determined by theoretical calculations and the results were verified by experimental observations. It has been observed that aerials of different lengths will radiate the energy along different channels and a typical record of observations for the intensity measurements has been shown with a half-wave radiator.

INTRODUCTION

Wireless communications with ultra-short waves have now grown to be fairly common due to their application in television, aircraft communications, upper-air weather observations, and various others. Due to the small size of these waves, special types of aerials have to be designed and hence the study of the variation of radiated field-strength in the neighbourhood of such aerials would be of great importance to the radio engineer. Such investigations have been made by various workers [1,2,3] with comparatively larger wavelengths and mostly with vertical aerials. In the present communication the intensity of the radiated field in the vicinity of an ultra-short-wave horizontal transmitting aerials was determined and the mode of its variation around the aerial has been investigated. A modulated oscillator was used to generate waves of 6.1 metres in length for

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the purpose. A regenerative ultra-short wave receiver was constructed to receive the signals generated by the oscillator. The generator was connected with a half-wave horizontal aerial which was placed in a fixed direction and the receiver was moved along the circumference of a circle with the input end of the transmitting aerial at the centre. The field-strengths were measured at different angular directions with respect to the orientation of the transmitting aerial. The observed field-strengths have been verified by the values of the same calculated mathematically. While moving round the aerial, several positions of maximum and minimum values of the field-strengths are obtained which have also been confirmed by theoretical calculation after finding out the proper conditions for the same. For the determination of absolute field-strengths, the receiver was calibrated, the method of which has been described in subsequent sections.

THEORY

Suppose OP in fig. 1 represents the horizontal radiating aerial and ABC is the circumference of a circle along which the receiver is moved in order to determine the field-strengths. The input end O of the aerial is situated at the centre of the circle. Let A be a point at which the signal-strength is to be determined, r_1 and r_2 are the distances from the ends O and P of the aerial to the point A respectively. The length of the radiating aerial is denoted by l.

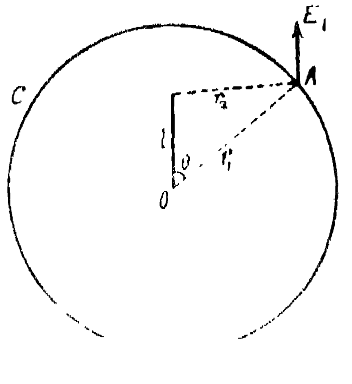


FIGURE 1

It has been shown by Carter[4] that the electric field-strength at any point in the vicinity of a straight radiating aerial and in the direction parallel to the length of the radiator is given by

$$E_1 = j30I \left[\frac{e^{-jmr_2}}{r_2}(-1)^n - \frac{e^{-jmr_1}}{r_1} \right] \text{ volts/cm.} \qquad \ldots \quad (1)$$

where I is the current in amperes flowing through the aerial, $m = 2\pi/\lambda$, λ being the wavelength radiated, and n is any positive integer depending on the length of the aerial.

Simplifying the above equation (1), we get,

$$E_r = -30I\left[j\left\{ \frac{\cos(mr_2)}{r_2} + \frac{\cos(mr_1)}{r_1} \right\} + \left\{ \frac{\sin(mr_2)}{r_2} + \frac{\sin(mr_1)}{r_1} \right\}\right] \text{volts/cm.} \qquad \ldots \quad (2)$$

From fig. 1, it will be seen that

$$r_2^2 = l^2 + r_1^2 - 2lr_1 \cos\theta,$$

where θ is the angle between r_1 and OP. Substituting this value of r_2 in equation (2) and neglecting the imaginary terms, we get

$$E_r = -30I\left[\frac{\sin(m\sqrt{l^2 + r_1^2 - 2lr_1\cos\theta})}{\sqrt{l^2 + r_1^2 - 2lr_1\cos\theta}} + \frac{\sin mr_1}{r_1} \right] \text{volts/cm.} \qquad \ldots \quad (3)$$

The present investigation was carried out with radiating aerials half wave-length long and the field-strengths were determined along the circumferences of concentric circles of various radii. A typical calculation for a circle of radius $3\lambda/4$ is shown below.

For calculation of field-strengths at the distances of $3\lambda/4$ from the input end of the radiating aerial in different directions, $\lambda/2$ is substituted for l and $3\lambda/4$ for r_1 in equation (3) and thus we get

$$E_r = -\frac{30I}{\lambda}\left[\frac{\sin 2\pi\sqrt{\frac{13}{16} - \frac{3}{4}\cos\theta}}{\sqrt{\frac{13}{16} - \frac{3}{4}\cos\theta}} - \frac{4}{3} \right] \text{volts/metre} \qquad \ldots \quad (4)$$

when λ is measured in metres.

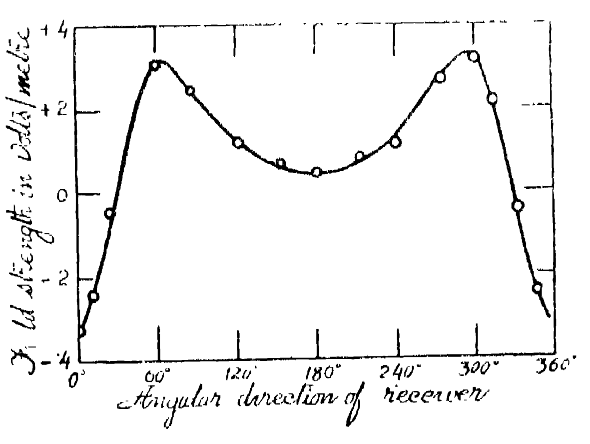


FIGURE 2

Various values of the field-strengths E_r have been calculated for different angular directions indicated by θ in equation (4) and they are shown in Table I, below. For the sake of convenience of indicating the directions of maximum and minimum values of field intensity the variation of field strength with angular directions has been depicted graphically in fig 2, which will be compared with such curves obtained experimentally shown later.

TABLE I

Angular direction of the receiver	Calculated field-strengths in volts/metre	Angular direction of the receiver	Calculated field-strengths in volts/metre
0°	−0.331	180°	0.064
10°	−0.290	210°	0.067
15°	−0.240	240°	0.105
20°	−0.170	270°	0.218
30°	−0.010	300°	0.328
45°	0.210	330°	−0.010
60°	0.328	340°	−0.170
90°	0.218	345°	−0.240
120°	0.105	350°	−0.290
150°	0.067	360°	−0.334

The approximate angular directions for maximum and minimum amounts of energy-flow will appear from the curve shown in fig. 2, the exact directions, however, were obtained by differentiating equation (4) and subsequently equating the expression obtained to zero.

Thus we get from equation (4)

$$\frac{dE_t}{d\theta} = \frac{30I}{\lambda}\left[\frac{\cos 2\pi\sqrt{\frac{13}{16}-\frac{3}{4}\cos\theta}\times\frac{3\pi}{4}\sin\theta-\frac{3}{8}\left(\frac{13}{16}-\frac{3}{4}\cos\theta\right)^{-\frac{1}{2}}\sin\theta\times\sin 2\pi\sqrt{\frac{13}{16}-\frac{3}{4}\cos\theta}}{\frac{13}{16}-\frac{3}{4}\cos\theta}\right] \quad \ldots (5)$$

Equating the right-hand expression of the above equation to zero, we get for the condition of maximum or minimum field-strengths,

$$3\pi^2\cos\theta+\tan^2 2\pi\sqrt{\frac{13}{16}-\frac{3}{4}\cos\theta}=\frac{13\pi^2}{4}. \quad \ldots (6)$$

Now, the above equation is satisfied for five values of θ, *viz.*, 19°40′, 66°38′, 160°20′, 293°22′ and 340°20′. In order to distinguish the angles corresponding to maximum and minimum values of field-strengths, equation (5) is differentiated once more and the positive or negative values of $d^2E_1/d\theta^2$ are determined for those angles.

Thus from equation (5) we get,

$$\frac{d^2E_1}{d\theta^2} = -\frac{3\pi}{4A}\cos\theta\cos 2\pi\sqrt{A} + \frac{3}{8A^{\frac{3}{2}}}\left\{\frac{3\pi^2}{2}\sin^2\theta\sin 2\pi\sqrt{A} + \cos\theta\sin 2\pi\sqrt{A}\right\}$$

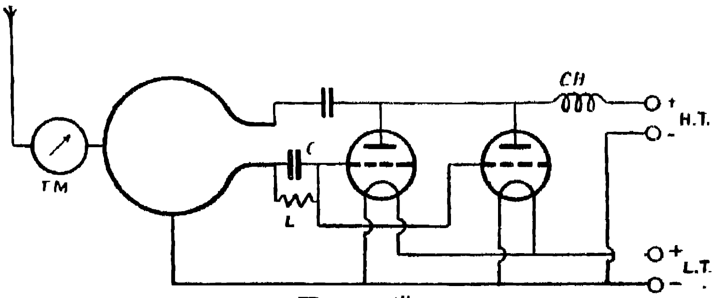
$$+\frac{27\pi}{32A^2}\sin^2\theta\cos 2\pi\sqrt{A} - \frac{27}{64A^{\frac{5}{2}}}\sin^2\theta\sin 2\pi\sqrt{A} \quad .. \quad (7)$$

where $\quad A = \frac{13}{16} - \frac{3}{4}\cos\theta.$

From equation (7) it can be shown that the angles 19°40′, 160°20′ and 340°20′ correspond to the minimum values of field-strengths and the angles 66°38′ and 293°22′ correspond to the maximum values.

The angular directions for the maximum and minimum radiation of energy will also be clear from fig. 2. It may be noted from fig. 2 that the highest value of the radiated field-strength is indicated only at 0° and 360° and as these angles do not correspond to maximum or minimum value of the field-strength, they do not satisfy equation (6). These mathematically calculated values of the angular directions were verified by experimental observations recorded in the next section.

EXPERIMENTAL ARRANGEMENT AND OBSERVATIONS



Transmitter

FIGURE 3

Transmitter. A parallel-fed modulated oscillator of Hartley type was built with two valves in parallel. The chematic diagram of this is shown in fig. 3. A constant modulation was effected by a leak L and a condenser C in the grid circuit. An ultra-short-wave choke CH was connected in the anode circuit. Aerial current was measured by a thermo-milliammeter TM. The oscillator could generate wave 6.1 metres in length. The aerial consisted of straight bare copper wire half wave-length long. The wave-length emitted by the oscillator was measured by a pair of Lecher wires and a thermo-galvanometer.

Receiver. The receiver for the measurement of the intensities of the radiated fields consisted of a leaky grid detector with reaction and a low frequency amplifier as shown in fig. 4. The regenerative type of receiver

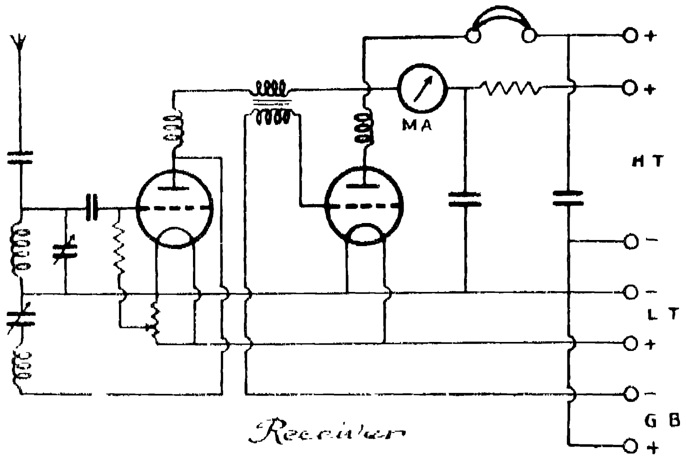


FIGURE 4

was specially preferred to a super-heterodyne or super-regenerative type for the convenience of calibration and stability at ultra-high frequencies. A milliammeter MA indicated the change in the plate current of the detector for calculating the field-strengths. The receiving aerial was of a similar type as employed in the transmitter but of a smaller length. The receiver was carefully screened and for the measurement of absolute values of field-strengths radiated it was calibrated. The usual method of calibration of such a receiver is inapplicable in the present investigation as the dimensions of the receiving loop would be comparable with the wavelength radiated for observations and hence the following method of calibration was adopted. The receiver was kept at a known distance from the transmitter and the transmitting aerial was excited by passing current through it which was recorded in the thermo-milliammeter. The radiated signal from the transmitting aerial was tuned by the receiver and the changes in the plate current of the detector was noted and the sound in the headphones in the second stage of the receiver was also heard. This observation was repeated with different independent values of currents flowing through the transmitting aerial. From the knowledge of the current flowing through the transmitting aerial the field-strength at the receiver was calculated from equation (3) given in the previous section. The calibration curve showing the field-strength for any value of the change of plate current under proper conditions is shown in fig. 5. Thus knowing the change in plate current when the receiver is tuned at any distance, the field-strength could

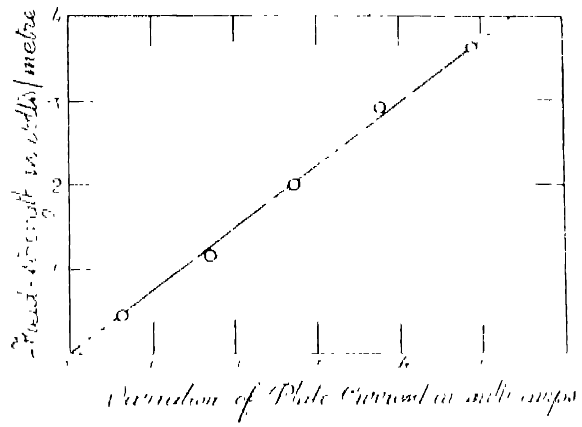


FIGURE 5

be readily obtained from the graph. The relative field-strengths were often checked by the headphones connected in the output of the receiver. The ultra-short-wave transmitter with the horizontal aerial was placed in an open space sufficiently above the ground. The signal strengths were measured at various points which were at distance of three-fourths of a wavelength in different directions from the transmitter. The various directions in which the observations were recorded were indicated by the angle which that direction made with the transmitting horizontal aerial. The receiving aerial was placed at the same height as the transmitting one and was always oriented in the direction parallel to the radiating aerial.

Table II below gives the values of the field-strengths experimentally observed in different directions from the transmitter. First column of the table shows the angular direction of the receiver from the transmitter and the second column indicates the corresponding observed field-strengths.

TABLE II

Angular direction of the receiver	Observed field-strengths in volts/metre	Angular direction of the receiver	Observed field-strengths in volts/metre
0°	0.335	180°	0.060
10°	0.288	210°	0.070
15°	0.244	240°	0.104
20°	0.165	270°	0.244
30°	0.010	300°	0.324
45°	0.210	330°	0.010
60°	0.324	340°	0.165
90°	0.244	315°	0.244
120°	0.104	350°	0.288
150°	0.070	360°	0.335

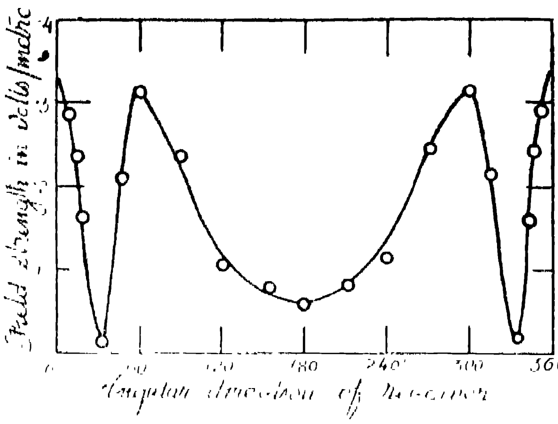


FIGURE 6

Fig. 6 shows the variation of the radiated field-strengths with different angular directions from the transmitter. It will be observed that the curve shown in fig. 6 will agree very closely with that shown in fig. 2 in the previous section, if we neglect the negative sign of the field-strengths in the latter. This will be also clear if the numerical values of the calculated and observed field-strengths, shown in Table I in the last section and Table II above, be compared without any reference to the direction of the fields.

SUMMARY AND CONCLUSION

Field-strengths in the vicinity of an ultra-short-wave horizontal aerial have been calculated and experimentally measured by means of a calibrated receiver. The directions of maximum and minimum amounts of energy-flow have been also determined by theoretical calculation and experiments. The transmitter consisted of a modulated valve oscillator with a half-wave radiating aerial, generating waves 6.1 metres long. The receiver consisted of a leaky grid regenerative detector and a low-frequeny amplifier. It has been concluded that the directions of maximum and minimum amounts of radiated energy from such an aerial depends on the lengths of the aerials employed, and the observations for a half-wave aerial have been recorded.

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